Summer 8-2014

A Case Study of Changing Cropping Diversity and Agricultural Risk in the Doulthabad Mandal of Telangana State in India

Srikanth Kondabolu
University of Nebraska-Lincoln, srikanthkondabolu@gmail.com

A CASE STUDY OF CHANGING CROPPING DIVERSITY AND AGRICULTURAL RISK IN THE DOULTHABAD MANDAL OF TELANGANA STATE IN INDIA

By

Srikanth Kondabolu

A THESIS

Presented to the Faculty of

The Graduate College at the University of Nebraska

In Partial Fulfillment of Requirements

For the Degree of Master of Science

Major: Natural Resource Sciences

Under the Supervision of Professor Michael J Hayes

Lincoln, Nebraska
August, 2014

A CASE STUDY OF CHANGING CROPPING DIVERSITY AND AGRICULTURAL RISK IN THE DOULTHABAD[1]MANDAL OF TELANGANA STATE IN INDIA

Srikanth Kondabolu, M.S.

University of Nebraska, 2014

Advisor: Michael J Hayes

The Doulthabad[1] Mandal is a hot semi-arid agro-ecological sub-region (Rao et al. 2006) located in Mahbubnagar District on the North Telangana Plateau in the state of Telangana[2]. Agriculture is the main occupation in this region, which is populated mostly with small and marginal farmers. This study uses the time period from 1971 to 2004 to study the variation in cropping pattern diversity and distribution of rainfall during the monsoons and understand the implications on production risk in agriculture. Quantitative methods were used in determining the changes in rainfall while qualitative methods were used to study cropping system changes. The analysis of rainfall data indicates a 5% increase in wet spell duration and a 5% decrease in wet spell intensity in the period from 1971-1990 to 1991-2004. The cropping system diversity in the same time period has decreased from 23 to 10 crops in the Kharif (monsoon) season with access to improved agricultural technology. These changes are also associated with a shift from intercropping to monocrop-based systems. The results indicate that these changes in cropping systems have resulted in a decreased management of production risk with increased investments in agriculture and lesser flexibility in the decision making on crops.

[1]Doulthabad is a Mandal (a sub divisional administrative unit of Districts in India) in Mahbubnagar District (an administrative unit of a state in India) of Telangana state in India.

[2]The new state of Telangana was formed on 2nd June 2014 after it had separated from the earlier state of Andhra Pradesh.

Table of Contents

CHAPTER 1: INTRODUCTION

India's agricultural growth trajectory post-independence (1947) has witnessed massive investments in agricultural research and extension, irrigation projects, rural infrastructure, farm credit and rural development programs. This has resulted in a transition from food crises in the 1960s to aggregate food surpluses in recent decades (Kerr 1996). The massive investments in irrigation across the country have ensured that around 40% of the net sown area is now irrigated whereas the remaining 60% is still rainfed. Even with full development of irrigation potential about 45% of the net sown area in India will still remain rainfed (Singh et al. 2010).

According to Kerr (1996), the agricultural growth story in India projects a differentiated picture of growth for rainfed and irrigated areas. In its initial years, the green revolution[3] was witnessed mostly in wheat and rice producing regions (areas irrigated under a network of canals from dams) and then spread to rainfed areas during 1980s with a very staggered approach. Despite this, the green revolution did not achieve the same net productivity gains as was experienced in irrigated regions.

Over the years there have been many definitions for rainfed areas that take into account the average rainfall of the region and percent of the gross cropped area under irrigation. Kerr (1996) summarized a variety of results that defined rainfed

[3] Green revolution involved importing of technologies in the high yielding varieties of seeds along with usage of fertilizers and provision of irrigation. Green revolution technologies introduced in India in 1965 in collaboration with the USA, were aimed at improving the agricultural production in India. Green revolution was first introduced in wheat before spreading to rice in its initial years. (Heitzman et al.1995)

agricultural regions as having less than 10-30 percent irrigation and an average rainfall of between 375-1500 mm. In India, around 60% of the total net sown area spread over 177 districts in various agro-climatic zones is under rainfed agriculture (Singh et al. 2010). In India 85% of the coarse cereals, 80% pulses, 70% oilseeds, 65% cotton and 45% rice are produced under rainfed farming systems[4]. Rainfed farming systems also constitute 78% cattle, 64% sheep and 75% goats in India.

Rainfed regions also have access to irrigation wells in almost every village, so irrigated and rainfed agriculture co-exist almost everywhere. The real difference in the classification of rainfed regions is in the fact that their total access to irrigation in the net cropped area is below 30% of the total agricultural area (Kerr 1996). The impact of the level of rainfall in these regions on agricultural production is essentially both a function of the intra-seasonal distribution of rainfall, and the moisture holding and retention capacity of the soils. This diversity in agro-ecology, socio-economic characteristics and resource availability does place a need to distinguish these regions for determining their agricultural development strategies. It is this necessity that has triggered the need to distinguish rainfed agriculture as a differentiated area for planning agricultural research and policies (Vijay Shankar 2011).

---

[4] Farming systems are defined as a population of individual farm systems that have broadly similar resource bases, enterprise patterns, household livelihoods and constraints, and for which similar development strategies and interventions would be appropriate (Dixon et al. 2001). In this case the farming systems are all bound together by their rainfed agro ecosystem.

The focus on rainfed regions is important because there regions are fragile ecosystems that display a large amount of diversity in both their natural resource base and the populations that inhabit these places. The range of diversity in rainfall patterns experienced by the rainfed regions coupled with the heterogeneity of the soils and the farming practices in each region add to the complexity in defining rainfed areas.

The diversity of livelihood activities of rainfed farmers is an important feature of rainfed farming systems. Rainfed farming systems cultivate more than 30 crops in contrast to 3-4 crops in irrigated agriculture, along with livestock, horticulture, agro-forestry and tank based inland fisheries. Rainfed farming systems reveal a diverse portfolio of production options that emphasise crucial relationships between natural resources, local resource management practices and livelihoods. The lack of adequate policy planning, instability in agricultural production and inability of green revolution technologies to provide the required production impetus has hindered agricultural growth in rainfed areas (Vijay Shankar 2011). The agricultural growth strategy involving input intensive agriculture has come at a socio-economic and ecological cost involving depletion of natural resources, soil health and declining groundwater levels (CRIDA 2011) and heavy distress-induced migration and dependence of cultivators on food supplied by the state (Narendranath 2010).

With the opportunities for continued expansion of irrigated agriculture becoming limited and a growing concern about the ecological and social consequences of the input-intensive agriculture, there is a need for planning and technology development to bridge the productivity gaps in rainfed agriculture (CRIDA 2011).

Risk in agriculture is associated with negative outcomes that stem from imperfectly predictable biological, climatic, and price variables (Alderman et al. 1992). These sources of risk can be classified into production risk, price or market risk, financial or credit risk and technology risk (Planning Commission, Government of India, 2006). Production risk, caused by fluctuations in the occurrence and distribution of the monsoons is a typical feature of rainfed agriculture in semi-arid tropics (Walker et al. 1990).

The onset of the southwest monsoon, which becomes active around mid-June and recedes by mid-October determines the growing season in rainfed agriculture. The onset of the monsoon or the occurrence of the first wet spell (explained in the methodology section), which determines sowing in rainfed regions, is highly uncertain. Delay in the onset of the monsoon, as well as lack of wet spells during critical growth stages of the crops, results in yield losses in rainfed agriculture due to water stress. Water stress during crop growth in rainfed agriculture, results in varying yield losses depending on (a) diversity of crops sown (b) variability in soil type (c) spatial variability of rainfall, and (d) diversity in crop management practices. Based on their period of occurrence these periods of prolonged water stress (agricultural droughts) can be categorized as early season drought, mid-season drought and terminal drought (Sharma et al. 2010).

The high intra-seasonal variability (this is discussed in detail in the methodology section) of monsoon rainfall places rainfed regions at a high incidence of rainfall-related risks. The consequences of these risks are potentially numerous and range from decreased agricultural production and income, to slower diffusion of more profitable but riskier technologies, increased indebtedness and also migration of families from agriculture (Walker et al. 1990). Using coefficient of variation (CV) as an indicator of instability in food grain production, rainfed regions exhibit an instability ranging from 19%-70% as compared to 8%-26% for irrigated regions (Shah and Sah 1993, Dhawan 1988).

With this context, the main purpose of this study is to depict the cropping pattern changes in rainfed regions brought about by green revolution technologies and integrate it with the changing scenario of risk. This is done in the form of a case study for the Doulthabad Mandal in the Mahbubnagar district of Telangana state with the following specific objectives:

1. To understand the intra-seasonal distribution of the monsoon within the Mandal, in the form of wet and dry spells, and analyze the occurrence and characteristics of wet spells in the time periods considered.
2. To depict the traditional multiple cropping systems and current cropping systems in the study area along with their sowing, harvesting and critical water requirement periods.
3. To examine the changes in the cropping systems with a discussion on the management of risk in rainfed agriculture.

CHAPTER 2: MATERIALS AND METHODS

a. Site Description

i. **Locality:** Telangana, a state on the southeastern coast of India has a net cropped area of 4.5 million hectares of which 2.5 million hectares (56% of net cropped area) are under Rainfed Agriculture (Directorate of Economics and Statistics 2011).

The study area constitutes the Doulthabad Mandal located in the northwest corner of the Mahbubnagar District in the state of Telangana. Doulthabad Mandal is located between latitudes 16.898^0N and 17.052^0N, and longitudes 77.467^0E and 77.667^0E. It is bounded by Sedam block[5] of Karnataka to its west, Kosgi Mandal in Telangana to its east

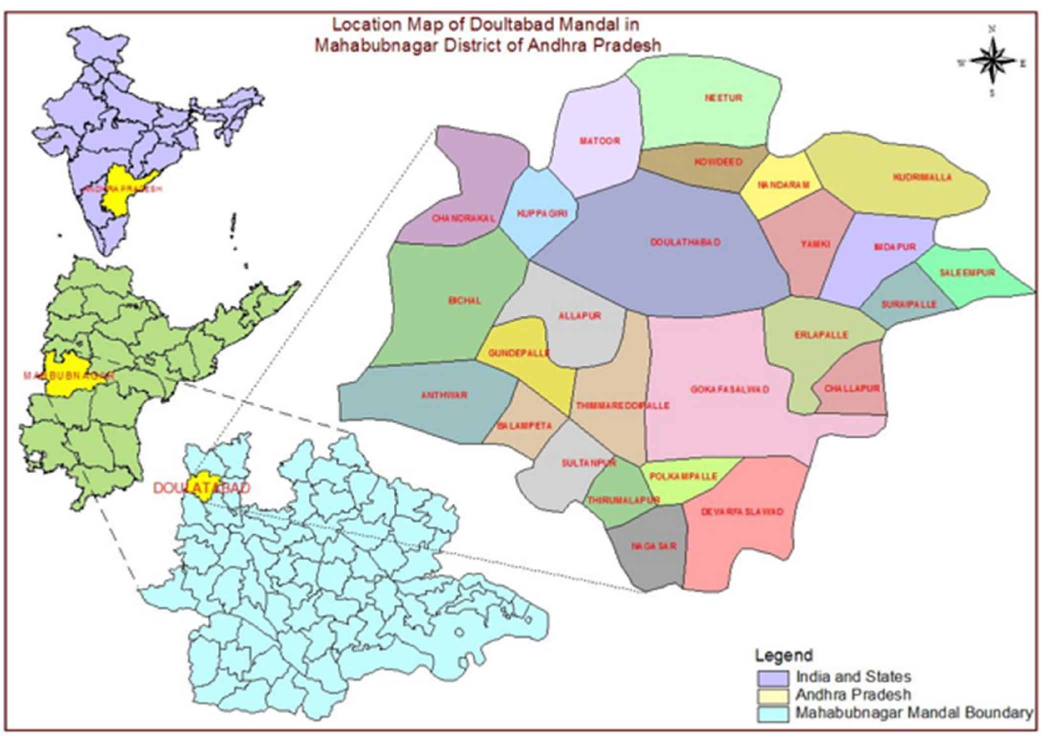

Fig 1: Location of the Doulthabad Mandal

Block is an administrative sub-division of the District which is used in all other states of India except Andhra Pradesh.

The Doulthabad Mandal has an aerial extent of about 18,304 hectares (Directorate of Economic and Statistics 2009) with 10,456 households having a population of 51,497 (Census of India 2011). Doulthabad Mandal constitutes of 20 Gram Panchayats[6]. Doulthabad Mandal has 10,797 producers in its population (Census of India 2011), which indicates almost every household in the Mandal being involved in agriculture.

ii. **Climate, Vegetation and Soil:** The Doulthabad Mandal has a hot semi-arid agro-climate with an annual precipitation of 650-700mm. The majority of the rainfall occurs in the South West monsoon between June and October. Even though there is not a very well defined dry season during the monsoons, the intra-seasonal distribution of monsoons mainly permeates the region through a series of wet and dry spells of varying intensities and time periods (Ranade et al. 2009).

Less than 30% of the total cropped area in the Mandal has access to irrigation from bore wells and minor irrigation tanks. The soil in this region is mostly loamy and clayey mixtures of black and red soils. Red soil or alfisols, with a low water retention capacity that makes them suitable only for Kharif or rainy season sowing, is mostly predominant in this region. Deep black clay soils or vertisols, with a high water retention capacity that makes it suitable for both Kharif or rainy season sowing and Rabi or post rainy season sowing is present in small clusters in the Mandal.

---

[6]Gram Panchayat is a local self-government institution at a village or town level. It is the smallest administrative unit in India.

The study area within the Doulthabad Mandal constituted 3 Gram Panchayats of Bichal, Imdapur and Devarafaslabad. These three villages were selected to reflect a geographical diversity in their spread across Doulthabad Mandal and also to represent the cropping practices in the two dominant soil types found in the region.

The Gram Panchayat of Bichal has a high concentration of black soils along with a considerable amount of red soils whereas Imdapur and Gundepally constitute mostly of red soils and have a very small amount of black soils.

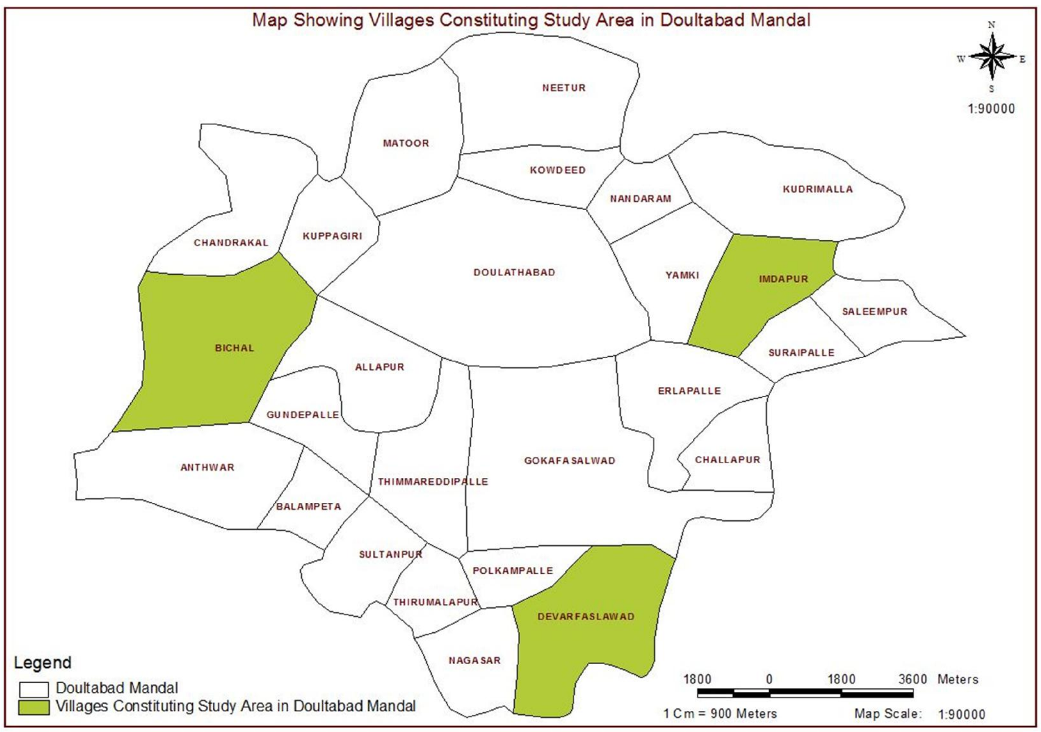

Fig 2: Map showing villages where study was conducted.

b. Methodology

This study involved a mixed methods approach to collect and analyze data. Data pertaining to rainfall and its analysis is done in a quantitative manner using secondary data available. While data relating to cropping systems and agronomic practices was collected qualitatively using semi-structured dialogue with focus groups.

i. Quantitative Analysis:

1. Rainfall Analysis: A high resolution daily gridded rainfall dataset from Rajeevan et al. 2008 was used for the purpose of this study. This is a 0.5*0.5 degree grid dataset with daily rainfall values from 1971-2005. The time period from 1971 to 2004 was considered for analysis in this study. The year 2005 was left out from the purview of this study as the rainfall in this year is highly aberrant and tends to skew the rainfall analysis. This time period is divided into 2 parts, one from 1971-1990 and the other from 1991-2004. Rajeevan et al. 2008 was the only available data source for daily rainfall for the study region at the 0.5*0.5 degree latitude-longitude spatial resolution. The lack of other reliable data sources for daily rainfall has limited the analysis of rainfall up through 2004.

In the focus group discussions with the farming community in the three study villages, the majority of the population involved in the discussion concurred to the time period when the cropping systems[7] changed from a traditional inter-crop based cropping system to the current input dependent mono-cropping systems to be around 1988-1992. In order to differentiate between the time periods when input intensive agriculture started having prevalence over

[7] Cropping system refers to crops, crop sequences and management techniques used over a period of time (FAO.1995)

traditional-based agriculture, 1990 is considered to be the year of transition in cropping systems and agronomic practices. The rainfall analysis is also broken up into 2 time periods from 1971-1990 and 1991-2004 to reflect these changes in cropping systems.

2. Defining dry and wet spells: As early as 1886, Indian tropical monsoon has been known to fluctuate between active spells and “intervals of drought” i.e. break spells (Blanford 1886). The terms “active” and “break” have been used to refer to fluctuations of cyclonic and anticyclonic vorticity above the boundary layer respectively (Ramamurthy 1969, Sikka et al. 1978). These active and break phases in the prorogation of the tropical monsoon circulation cause the wet and dry spell in the occurrence of monsoon rains.

   In Singh et al. (2009), the authors define wet spells (dry spells) as continuous periods with daily mean rainfall being equal or greater (lesser) than the daily mean rainfall from the climatological average for the region. In the same paper, Singh et al. (2009) use this definition to analyze rainfall data in the study region of which the Doulthabad Mandal is a part, and state that this region has average wet spell (dry spell) duration of 7.9 days (14.6) with an intensity of 8.9mm (1.3mm). They also state that the wet spells contribute to 70.1% of the total rainfall received in the region. The daily rainfall data of the country on 1*1 degree latitude-longitude spatial resolution for the period 1951-2007 developed by Rajeevan et al. (2006) was used in the study by Singh et al. (2009).

The definition of wet spells in Singh et al. (2009) focuses mostly on the meteorological characteristics of rainfall while they might not hold true in defining agricultural wet spells. Neither does this definition of wet spell take into account the daily evapotranspiration of the region which is the basis for agricultural wet spells nor does it factor soil moisture retention capacity which can account for ET requirements even on days without rainfall. Taking these limitations in the definition of wet spells in Singh et al. 2009 into account, this study tries to define agricultural wet spells in the following manner:

- The ET of Doulthabad is considered to be in the range of 4-5mm/day (Rao et al. 1970)
- Using mean wet spell duration of eight days (approximated value) from Ranade et al. (2009), eight or more day periods are selected such that they meet the ET requirements of the time period (i.e. rainfall in the range of 32-40 mm should occur in a span of 8 days).
- This wet spell should start on a rainy day as defined by Indian Meteorological Department (i.e. rainfall on the starting day should be greater than 2.5 mm).
- The soil being mostly alfisols (red loamy soils), the soil water retention capacity at any point of time cannot be more than 50mm (Kanwar 1982, Virmani et al. 1978).
- These criteria are used to define agricultural wet spells in this study with every period other than the wet spell being considered as a dry spell.

This study then analyzes the characteristics of the wet spells (such as duration and intensity) to check for any changes in the two time periods considered in the study. A statistical analysis using a two way t-test was done to check the significance of the changes in the wet spell characteristics in the two time periods considered in this study.

3. Defining drought: India Meteorological Department (IMD) defines Meteorological Drought based on rainfall deficiency of the southwest monsoon (June-September) on sub-division wide basis for the country as a whole. The meteorological droughts are classified into moderate and severe based on rainfall deficiency, i.e. 26 to 50% and more than 50% respectively, of the long term climatological average. In India, a year is considered to be a drought year when the area affected by moderate and severe drought, either individually or together, is 20 - 40 % of the total area of the country and seasonal rainfall deficiency during south-west monsoon season for the country as a whole is at least 10% or more (APDAI 2008, Ramachandran 2000). The Government of India adopts the definition of IMD in declaring droughts in India.

   Monsoon rainfall is characterized with a lot of intra-annual spatial and temporal variations across the different regions of the country, along with exhibiting a high inter-annual variability of 40% (Ramachandran 2000). Such high inherent variability implies that the probability of occurrence of droughts with 25% variability is very high in India.

The definition adopted by the government of India has a higher threshold of rainfall deficiency (25% of long-term average rainfall) to define drought. In semi-arid agro climates, which are characterized by high spatial and temporal variability of monsoon rainfall, a deficiency of monsoon rainfall lesser than 25 % of the long-term average spread temporally across the monsoon season is capable of inducing water stress in crops leading to a drought. Therefore, for the purpose of this study, the definition of drought adopted by the former state of Andhra Pradesh is adopted in this study. The Government of Andhra Pradesh, states that a monsoon with a deficiency of 15% from the long term average rainfall in regions having rainfall less than 750 mm can be defined as a drought (Venkateswarlu 2012).

Definitions of drought exist at a suitable aggregation of space (i.e. at a level of a group of districts, referred to as a sub-division by IMD) from the point of view of convenience for policy planners and only make use of meteorological data. These definitions fail to qualify the developing situation of drought in the area encompassing the sub-division, owing to the variability associated with rainfall within the sub-division. This is particularly true in the case of regions with an arid agro-climate where any deviation in rainfall during the growing season could exacerbate the water stress thereby impacting productivity, leading to drought like conditions.

The problems associated with defining drought also arise from the inability to quantify the threshold of drought even in the case of agriculture, for different agro-climates. The diversity of crops sown, along with their variations in the time of sowing, results in different crops requiring different amounts of rainfall for their growth and maturity during different phases of their growth stages. This demands definitions of drought that take into consideration the evapotranspiration requirements of regions smaller than the sub regions considered by IMD in qualifying droughts.

ii. Qualitative Analysis:

1. Data Collection: Data relating to cropping systems, agronomic practices and biophysical relationships between rainfall and crop growth were collected through semi-structured dialogues with small focus groups of 3-5 farmers. Two to three such semi-structured dialogues were conducted in each village, with a total of seven focus groups being carried out. A total of 24 farmers, which involved a mix of male and female farmers, were part of the data collection exercise in this study. For ease of use in interactions with the farmers, the locally understood "*Karthe*[8]" calendar was used in data collection and also in the results section of this study.

---

[8] A " Karthe" is a basic unit of the Telugu (regional language spoken in the state of Andhra Pradesh) calendar which is designed to coincide with the Full Moon or the New Moon. In a given year "Karthe" are 27 in number with the number of days in each "Karthe" ranging from 13-15 days.

The traditional agricultural knowledge in terms of the sowing, harvest and other agricultural activities use Karthe as a reference point. The Telugu calendar has been used in the collection and analysis of qualitative data pertaining to traditional knowledge and practices on cropping systems.

For the purpose of selecting study villages, all the villages in the Doulthabad Mandal were organized on the basis of their dominant soil type's viz. red and black soils. After this categorization it was observed that 16 villages had red soils as their dominant soil type while 9 villages had black soils as their dominant soil type (Annexure-1). Then the study villages were identified through a random selection of one village from the dominant black soils category and two villages from the dominant red soils category. The selected villages were then approached through a representative of the self-help group's[9] existent in the village. The representative would then organize the members required for a focus group discussion.

The focus groups were thus selected so that the biases arising out of access, hierarchy, gender and diversity were minimized. Depending on the size and the social distribution of the village, the focus group discussions were spread all through the village to minimize biases of hierarchy and diversity. Gender bias was minimized by making sure that each focus group constituted at least one woman farmer. These focus groups were conducted either in the early mornings or late evenings to minimize access bias (as farmers are away at the fields during most of the day). These focus groups usually lasted for about 60-75 minutes and were conducted near the house of one of the participant farmers in the focus group. The list of

[9] A self-help group (SHG) is a village-based financial intermediary usually comprising 10–20 local women or men who make small regular savings contributions over a few months until there is enough capital in the group to begin lending.

villages along with the number of participants in each village is presented in table 1.

Village	No of Focus Groups	No of Participants
Bichal	3	11
Imdapur	2	6
Devarafaslabad	2	7

Table 1: List of study villages along with total number of participants and focus groups in each village.

During the process of the qualitative data collection, different iterations of data collection was initially tried out such as individual interviews with farmers (including both men and women), and focus group discussions with specific gender groups (men and women separately). In this process, the questionnaire used for the study was also firmed up to better reflect the data requirements for analysis of qualitative data. The final data collected from the seven focus groups for this study, was then validated from the data collected in earlier iterations. If there was a major difference observed in comparison of the two datasets, another iteration of the study was conducted to check which dataset is more valid. In this manner the individual biases arising out of data collection with focus groups was kept under check.

The semi-structured dialogue technique was selected because of its ease in facilitating dialogues with focus groups. Semi-structured dialogues are more suited in engaging with group dynamics as they eliminate the negative effects of questionnaires like closed issues, lack of dialogue and failure to connect to the participant perceptions (Geilfus 2008).

The focus groups were conducted with reference to the questionnaire (see Annexure 2) with the researcher serving as the facilitator for the discussion. The questions were thus raised to initiate discussion and the conclusions for each question were recorded on charts of paper. These data collected were focused mainly around the farming system of the participants, viz. the crops sown and their agronomic practices. Data pertaining to sowing and harvesting windows for different crops and their rationale, along with farmer's perception of critical water requirements for these crops was also collected.

This grouping of years, for collecting and analyzing data, although appears to be logical in the context of the analysis for the study, is inadequate in getting information on changes in crops and cropping systems at a much shorter interval. This is particularly so, as this information is based on the recall from the collective memory of the farmers in the focus group. While the difficulty in collecting data related to traditional cropping systems lies with the expectations around a farmer recalling a large amount of data from his memory, this was addressed by doing multiple discussions with focus groups by building on what the earlier group had said. This information was then collated to obtain the matrix of traditional cropping systems presented in this study.

This problem of getting information on the changes in crops and cropping systems was particularly limiting post 1990 where changes in access to agricultural technology, irrigation, credit along with government policies have continuously had a bearing on the decision making process of the farmer. This change in diversity of crops is difficult to capture from recall in the focus groups. The cropping system mentioned under current cropping system refers to the most recent crops and cropping system in practice by the farmers.

2. Data Analysis: These data collected mainly constituted of components of the farming system, cropping systems, sowing and harvesting window, agronomic practices with reference to dry and wet spells of the monsoon, impacts of droughts and management practices to reduce risk in the event of a drought. The data were then synthesized such that the data relating to the farming systems i.e. crops sown, sowing and harvesting windows, critical water requirement period of crops and cropping patterns were tabulated to represent the characteristics of farming systems in each time period considered in this study. The other qualitative data were then analyzed to explain the rationale for the changing scenario of risk and the farmer's decision making process in each of these time periods in the discussion section.

3. Risk Analysis: The emphasis of this study is on understanding weather related production risks in semi-arid tropics and its management. This study tries to analyze production risk through adoption of risk coping and

risk management strategies (Alderman et al. 1992). Risk management refers mostly to the in-situ practices (e.g., contingency planning, agronomic practices, etc.) adopted to minimize the impact of weather related risks on production while risk coping refers to practices (e.g., crop insurance, storage of agricultural products, borrowing and lending, etc.) which prepare the farmer to bear the impacts of the weather related risks. As this study analyzes in-situ practices and their bearing on risk, factors constituting risk management were only considered for the purpose of this study.

Risk management strategies adopted by the farmers in their cropping practices are collected in the form of qualitative data through focus group discussions. These strategies are then discussed in relation to the changing monsoon distribution to get a scenario of changing risk in agriculture and its management with changes in cropping systems.

CHAPTER 3: RESULTS

A. Rainfall Analysis

i. Occurrence of Drought:

Analysis of daily rainfall on an annual basis for the time period in consideration reveals that the Doulthabad Mandal has been subject to drought (annual rainfall less than 15% of the long-term mean) in 14 of the 34 study years (Fig 3). Basing on the occurrence of droughts in the time period, it could be said that drought has a likelihood of occurring once every three years in the study region.

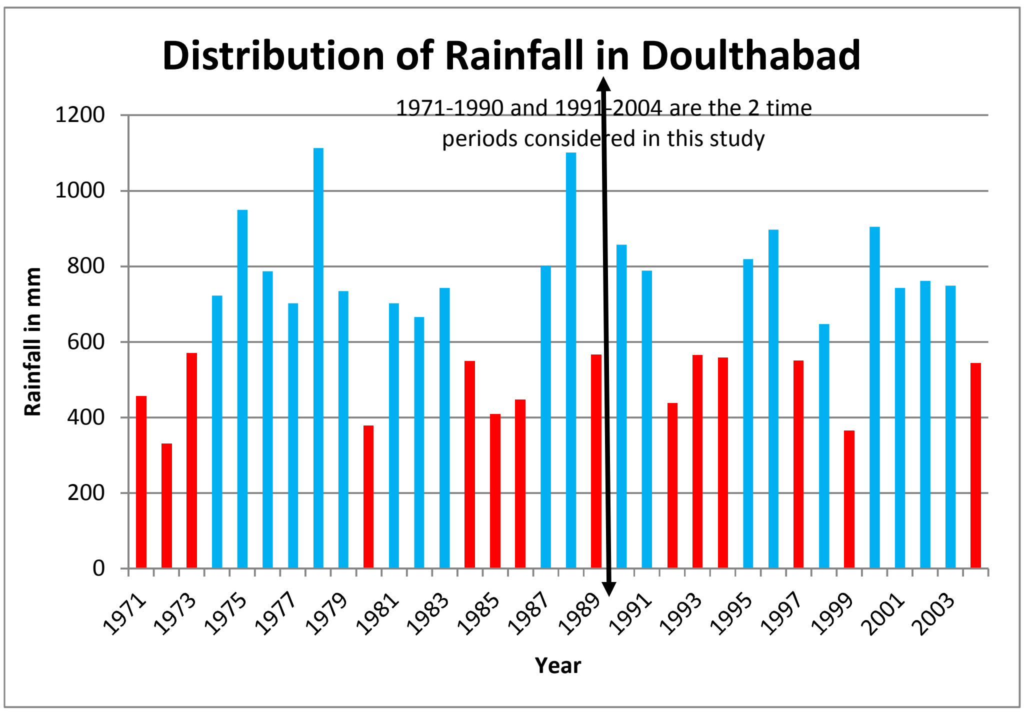

Fig 3: Distribution of annual rainfall in Doulthabad Mandal. 14 out of 34 years are drought years. The years in red indicate drought years while those in blue indicate normal monsoon years.

ii. Dry and wet spells within a monsoon:

Figure 4 shows a random selection of cumulative rainfall distribution in drought years 1971 and 1999 and normal rainfall years 1982 and 2003. As is evident in Fig 4, both normal rainfall years and drought years show a distribution of rainfall in dry and wet spells. These graphs illustrate the propagation of monsoons through events of wet and dry spells. A detailed list of wet and dry spells all through the time period is shown in Annexure 3.

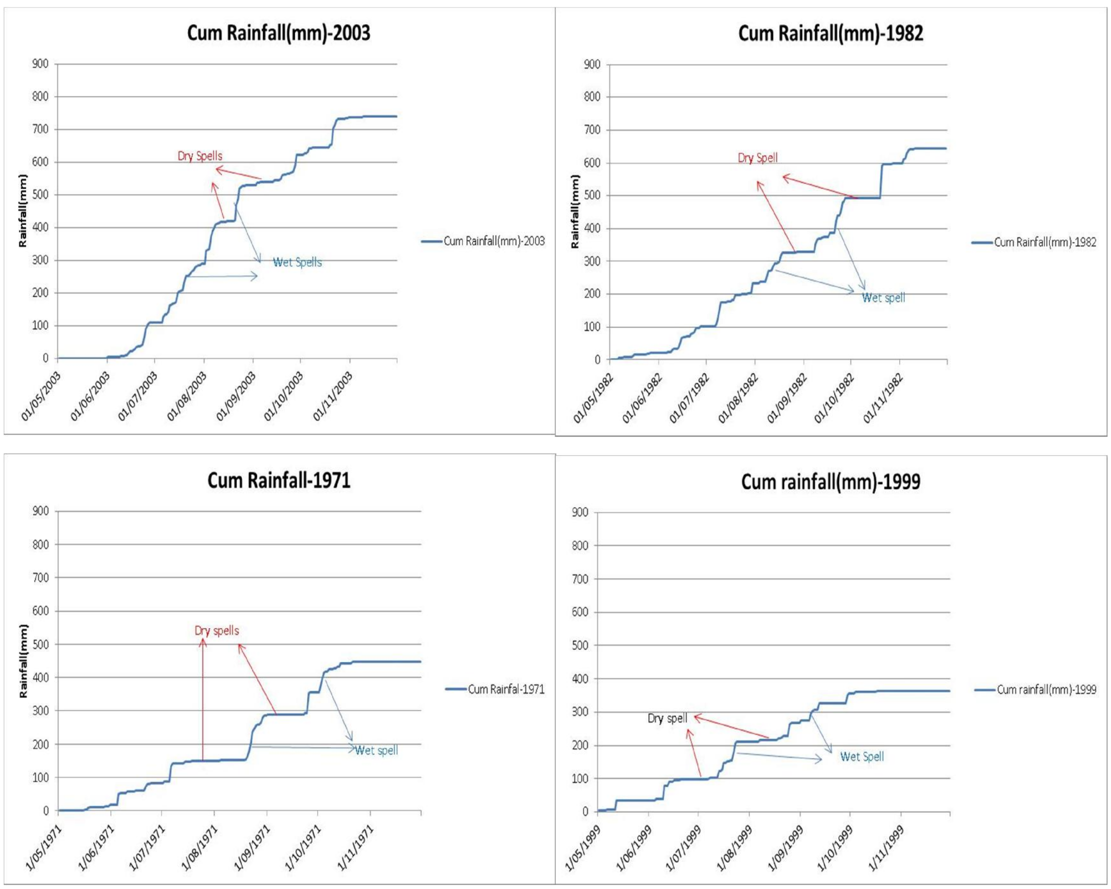

Fig 4: Four years were selected such that two years from each time period 1971-1990 and 1991-2004 are displayed. 1982 and 2003 are years of normal rainfall while 1971 and 1999 are drought years. The intra-seasonal distribution of rainfall in both drought and normal years shows the propagation of the monsoon in stretches of wet and dry spells.

iii. Changes in wet and dry spell characteristics in the two time periods in consideration:

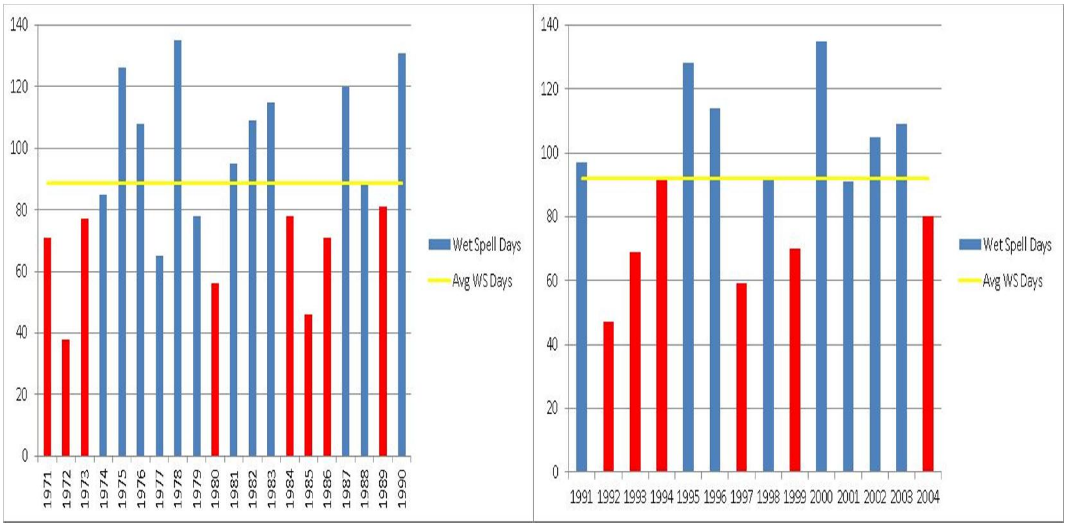

Fig 5: This figure depicts the wet spell days in each time period along with the average wet spells in the time period. The bars in blue indicate normal rainfall years while those in red indicate drought years.

The shift in the time periods from 1971-1990 and 1991-2004 show marked changes in the characteristics of wet and dry spells. The time period from 1971 to 1990 in Figure 5 shows that three (1974, 1977, 1979) of the twelve normal rainfall years in the time period have lower than average wet spell days for the time period. Whereas the time period between 1991 to 2004 does not have a single normal rainfall year with wet spell days less than the average for that period. This concentration of higher rainfall in a shorter duration of wet spell is indicative of higher intensity of rains in the time period from 1971-1990.

Time Period	Average Total Rainfall(mm)	Wet spell as percent of total monsoon rain (%)	Average wet spell duration in a year(days)	Average wet spell intensity in a day (mm/day)
1971-1990	679.37	82.36	88.65	6.34
1991-2004	666.24	82.71	92.00	6.00
p value	0.29	0.39	0.73	0.29

Table 2: The contrasts in total rainfall and characteristics of the wet spells between the time periods in consideration are brought about in this table. The statistical analysis for the equality of the means of the variables considered in the study across the two time periods is represented by the p value in the table.

A detailed analysis of wet and dry spells for the study period in Annexure 3 also indicates the concentration of higher rainfall in shorter duration of wet spells in the time period from 1971-1990 in Table 2. 1991-2004 also displays a 5% decrease in the average wet spell intensity as compared to 1971-1990, while the contribution of wet spell as percentage of the total monsoon has remained unchanged in both the time periods. These results involving changes in wet spell intensity and duration do not show any statistical significance, as indicated in Table 2.

The results indicated in Table 2, although not statistically significant find resonance in the general perception of farmers which came across in the process of data collection where the farmers felt that the intensity of rains has decreased in the recent years. For example one farmer in a focus group said that "*...before there used to be rains that flooded the streets of the village in a very short span of time, now such rains are nowhere to be seen...*". This transcript is a translated version of what the farmer had shared.

B. Cropping system analysis

i. Cropping system from 1971-1990

The overall crops and cropping diversity, which was prevalent in the 1971-1990 time period in the three study villages was recorded in the focus groups and is reported in Table 3. The crops prevalent in the time period show a diverse range of cereals (Finger Millet, Little Millet, Sorghum, Foxtail Millet, Pearl Millet, and Paddy), pulses (Red Gram, Black Gram, Green Gram, Bengal Gram, Cowpea) and oil seeds (Safflower, Sunflower, Niger, Sesame) along with Tymol Seeds. The cropping pattern in this time period was more adapted to meet the consumption requirements of the households and is reflected in the diversity of cereals, pulses and oilseeds that are evident in Table 3. The seed used for these crops were mostly landraces[10] which were in use in the region for a long time. A range of varieties within crops as in the case of Sorghum, Horse Gram and Red Gram are also seen.

Crop	Telugu name	Crop Variety	Soil Type	Irrigated/Rainfed	Crop Duration (months)
Finger Millet	Tydalu	Local	Red Soil	Rainfed	3
Little Millet	Samalu	Local	Red Soil	Rainfed	3-3.5
Sorghum	Pacha Jonnalu	Local yellow peri carp Sorghum	Red Soil	Rainfed	3-3.5
	Tella Jonnalu	Local white peri carp sorghum	Black Soil	Rainfed	3-3.5
Horse Gram	Nalla Ulavalu	Local black peri carp horse gram	Red Soil	Rainfed	3
	Bhoota Ulavalu	Local	Red Soil	Rainfed	3
	Tella	Local white peri	Red	Rainfed	3

[10] A local cultivar or animal breed that has been improved by traditional agricultural methods

	Ulavalu	carp horse gram	Soil		
Ground Nut	Palli	Local	Red Soil	Rainfed	4.5-5
Pearl Millet	Sajjalu	Local	Red Soil	Rainfed	3.5
Foxtail Millet	Korralu	Local	Red Soil	Rainfed	3.5-4
Red Gram	Erra Kandulu	Local red peri carp Red Gram	Black Soil	Rainfed	6.5-7
	Tella Kandulu	Local white peri carp red gram	Red Soil	Rainfed	5
	Nalla Kandulu	Local black peri carp red gram	Red Soil	Rainfed	5
Green Gram	Pesarlu	Local	Red Soil	Rainfed	3.5-4
Tymol Seeds	Vamu	Local	Black Soil	Rainfed	4-4.5
Sesame	Manchi Nuvvulu	Local	Red Soil	Rainfed	4-4.5
Niger	Gaddi Nuvvulu	Local	Red Soil	Rainfed	4.5-5
Cowpea	Bebberlu	Local	Red Soil	Rainfed	3.5-4
Safflower	Tella Kusumalu	Local	Black Soil	Rainfed	3-3.5
Sunflower	Nalla Kusmalu	Local	Black Soil	Rainfed	4-4.5
Bengal Gram	Manchi Senegalu	Local	Black Soil	Rainfed	4
Black Gram	Minmulu	Local	Black Soil	Rainfed	3.5-4
Paddy	Vadlu	Local	Black Soil	Irrigated	5.5-6

Table 3: Overall cropping diversity which was prevalent in the 3 study villages.

The compilation of cropping diversity in Table 3 is an aggregate of all crops sown in the three study villages. The cropping systems are more or less the same in all the villages with very minor variations. Bichal, with a higher proportion of black soils, has crops like Niger and Bengal Gram sown in the Kharif (monsoon crop). These crops are not very prevalent during the same period in the other study villages (Devarafaslabad and Imdapur) which have a higher concentration of red soils.

The interactions with the farmers revealed that row inter-cropping was commonly practiced while mixed inter-cropping happened in very minimal cases. Niger was the only crop which was in mixed cropping with Ground Nut, Horse Gram and Sesame. A list of all inter-crop combinations that were practiced in this time period is given Table 4.

S No	Main Crop	Inter-crop Combination
1	Green Gram	Cowpea
2	Cowpea	Red Gram, Ground Nut
3	Black Gram	Red Gram
4	Little Millet	Green Gram, Cowpea
5	Sorghum	Red Gram
6	Red Gram	Sorghum(Yellow peri carp), Green Gram, Cowpea, Pearl Millet, Black Gram, Foxtail Millet, Niger
7	Ground Nut	Green Gram, Cowpea
8	Paddy*	-
9	Finger Millet*	-
10	Tymol Seeds*	-
11	Pearl Millet	Red Gram
12	Foxtail Millet	Green Gram, Red Gram, Cowpea
13	Niger	Mixed Crop with Ground Nut, Horse Gram, sesame
14	Sunflower	Sorghum
15	Horse Gram*	-

16	Safflower	Sun Flower
17	Bengal Gram*	-
18	Sesame*	-
*These crops were mono cropped		

Table 4: Inter-crop Combinations that were prevalent in the study period from 1971-1990.

Table 5 represents the sowing and harvesting intervals of crops. This table is arranged in sequence with the local Telugu calendar of "*Karth*e" (Telugu is the language spoke in the state of Andhra Pradesh while "Karthe" refers to the month according to the Telugu Calendar) with the starting date of Karthe mentioned in the table. The cropping systems from 1971-1990 exhibits a much dispersed nature in sowing intervals which is spread all throughout the monsoon season from late May to early November. This cropping system also reflects a very high net usage of land, where usage of the same land for the multiple crop cycles within the monsoon season was a very common practice.

Crop	Telugu name	Rohini	Mirugu	Arudra	Pushyami	Punarvasu	Aslesha	Makha	Pubba	Uttara	Hasta	Chitta	Swati	Vishaka	Anuradha
Green Gram	Pesarlu														
Cowpea	Bebberlu														
Black Gram	Minumlu														
Little Millet	Samalu														
Sorghum	Pacha Jonnalu														
Red Gram	Erra Kandulu														
	Tella Kandulu														
	Nalla Kandulu														
Ground Nut	Palli														
Paddy	Vadlu														
Finger Millet	Tydalu														
Tymol Seeds	Vamu														
Pearl Millet	Sajjalu														
Foxtail Millet	Korralu														
Niger	Gaddi Nuvvulu														
Sunflower	Nalla Kusmalu														
Horse Gram	Tella Ulavalu														
	Nalla Ulavalu														
	Bhoota Ulavalu														

Safflower	Tella Kusumalu														
Bengal Gram	Manchi Senegalu														
Sesame	Manchi Nuvvulu														
Sorghum	Tella Jonnalu														
Index			**Karthe in which Sowing takes place**					**Karthe in which harvesting takes place**							

Table 5: Sowing and harvesting windows of crops grown in the time period from 1971-1990 according to Telugu Karthe. The relation between the Karthe and the Gregorian calendar is explained in Annexure 4.

Crop	**Telugu Name**	Rohini	Mirugu	Arudra	Pushyami	Punarvasu	Aslesha	Makha	Pubba	Uttara	Hasta	Chitta	Swati	Vishaka	Anuradha
		Critical Water requirement period of crops													
Green Gram	Pesarlu														
Cowpea	Bebberlu														
Black Gram	Minumlu														
Little Millet	Samalu														
Sorghum(Yellow)	Pacha Jonnalu														
Red Gram	Erra Kandulu														
	Tella Kandulu														
	Nalla Kandulu														
Ground Nut	Palli														
Paddy	Vadlu														
Finger Millet	Tydalu														
Tymol Seeds	Vamu														

Pearl Millet	Sajjalu														
Foxtail Millet	Korralu														
Niger	Gaddi Nuvvulu														
Sunflower	Nalla Kusmalu														
Horse Gram	Tella														
	Nalla Ulavalu														
	Bhoota														
Safflower	Tella Kusumalu														
Bengal Gram	Manchi Senegalu														
Sesame	Manchi Nuvvulu														
Sorghum(White)	Tella Jonnalu														
Index			**Good rain is required in this Karthe**				**Marginal rain/soil moisture/dew is sufficient in this Karthe**								

Table 6: This table contains the critical water requirements of crops during their growth stages according to Telugu Karthe. The relation between the Karthe and the Gregorian calendar is explained in Annexure 4.

Table 6 represents the critical water requirements of the crops that were prevalent from 1971-1990. This figure demonstrates that the number of crops that require marginal rain, dew, or a small amount of soil moisture during their critical period constitute 12 of the 23 varieties of crops that are grown during the monsoons. The crops that require good rain constitute 11 of 23 crops grown in this time period.

The growing periods of crops are also distributed so that their temporal spread of critical water requirement periods is dispersed throughout the monsoons. Crops like green gram, black gram, sorghum (yellow peri carp) have water requirement periods in the early monsoon season around mid-June while crops like Red Gram, Finger Millet, and Ground Nut have water requirement periods from June to October.

In the interactions with the farmers it did come across that the cropping systems that prevailed in the time period from 1971-1990 were rooted in the traditional agricultural practices that were in tune with the resource base of these regions and were intended to cater to all the household food requirements. This argument also finds resonance in Singh and Jodha (1986) wherein they refer to inter-cropping as a response to physical resource endowments with no particular emphasis on risk aversion in their decision making process.

ii. Current Cropping systems (1991-2004):

The cropping systems in this time period show a considerably reduced cropping diversity as compared to the time period from 1971-1990. In Imdapur and Devarafaslabad villages Red Gram is the dominant rainfed crop occupying about 60-70 percent of the total rainfed area. The remaining rainfed land constitutes area under green gram and ground nut. Bichal with its higher concentration of Black soils is witnessing the inclusion of Maize and Cotton in its cropping system in the recent years replacing red gram on rainfed lands. Paddy is an irrigated crop with flood irrigation while ground nut is irrigated under micro-irrigation with sprinklers.

The seeds used for Red Gram still constitute the local varieties which were in use traditionally while improved varieties of seeds are used for Green Gram, Ground Nut, Maize, Cotton and Paddy. Inter-cropping as an agronomic practice has shown a considerable decease in cropping systems. Red Gram is the only crop taken up in row inter-cropping with sorghum (yellow peri carp).

Table 7 represents the current cropping systems that are being practiced by the farmers, while Table 8 depicts the sowing and harvesting intervals of crops. The cropping system in this time period exhibits a very concentrated sowing window with 70% of the crops having a sowing window in between May 25th and June 22nd. Sorghum (White Peri Carp) and Ground Nut have a sowing window around late October and mid-September and rely on the North East Monsoon for their water requirement. Paddy with a sowing window in the range from late May to early August is an irrigated crop but, of late, with depleting ground water levels it relies on the monsoon to recharge the aquifers for a crop to be grown.

Crop	**Telugu name**	**Variety**	**Soil Type**	**Iriigated/ Rainfed**	**Crop duration (months)**
Red Gram	Utalam Kandulu	Local	Red Soil	Rainfed	6
	Erra Kandulu	Local	Red Soil	Rainfed	5
Green Gram	Pesarlu	Local	Red Soil	Rainfed	3.5-4
Cotton	Patti	Hybrid(Bt)	Black Soil	Irrigated	7
Paddy	Vari	Improved Variety	Red Soil	Irrigated	5-5.5
Maize	Mokka Jonna	Hybrid	Red Soil	Rainfed	4-4.5
Black Gram	Minumulu	Local	Red Soil	Rainfed	3.5-4
Yellow peri carp Sorghum	Pacha Jonnalu	Local	Red Soil	Rainfed	3-3.5
White peri carp Sorghum	Tella Jonna	Local	Black Soil	Rainfed	3.5-4

Ground nut	Palli	Improved Variety	Red Soil	Irrigated	4-4.5

Table 7: Sowing and harvesting windows of crops grown in the time period from 1971-1990.

Table 9 represents the critical water requirements of the crops that were prevalent in this time period. This figure demonstrates that the number of crops that require marginal rain or dew or a little amount of soil moisture during their critical period constitute two (white peri carp sorghum, black gram) of the eight varieties of rainfed crops that are grown during the monsoons. Both these crops are grown only in black soils making Bichal the only village where these crops are cultivated. The crops that require good rain constitute six (red gram, green gram, yellow pericarp sorghum, cotton, maize) of eight rainfed crops grown in this time period.

Crop	**Telugu name**	Ro hi ni	Mi rug u	Ar ud ra	Pus hya mi	Pun arva su	Asl esh a	M ak ha	Pu bb a	Ut tar a	H as ta	C hit ta	S w ati	Vis hak a	Anu radh a
Green Gram	Pesarlu														
Sorghum(Yellow peri carp)	Pacha Jonna														
Black Gram	Minumulu														
Red Gram	Utalam Kandulu														
	Erra Kandulu														
Cotton	Patti														
Maize	Mokka Jonna														
Sorghum(White Peri	Tella Jonna														

Carp)															
Ground nut	Palli														
Paddy	Vari														
Index			**Karthe in which Sowing takes place**					**Karthe in which harvesing takes place**							

Table 8: Sowing and harvesting windows of crops currently sown are indicated in this table according to Telugu Karthe. The relation between the Karthe and the Gregorian calendar is explained in Annexure 4.

Crop	**Telugu name**	Rohini	Mirugu	Arudra	Pushyami	Punarvasu	Aslesha	Makha	Pubba	Uttara	Hasta	Chitta	Swati	Vishaka	Anuradha
Green Gram	Pesarlu														
Sorghum(Yellow)	Pacha Jonnalu														
Black Gram	Minumulu														
Red Gram	Utalam Kandulu														
	Erra Kandulu														
Cotton	Patti														
Maize	Mokka Jonna														
Sorghum(White)	Tella Jonnalu														
Ground nut	Palli									Irrigated crop					
Paddy	Vari	Irrigated crop													
Index				**Good rain is required in this Karthe**					**Marginal rain/soil moisture/dew is sufficient in this karthe**						

Table 9: The critical water requirement periods of the current crops are indicated in this table according to Telugu Karthe. The relation between the Karthe and the Gregorian calendar is explained in Annexure 4.

CHAPTER 4: DISCUSSION

a. Changes in dry and wet spells:

Broad changes in characteristics of wet spell occurrences can be identified in the two time periods from 1971-1990 and 1991-2004 with a decreasing intensity of wet spells combined with an increase in total wet spell duration. Shorter wet spells of around 9 days followed by relatively longer dry spells of around 14 days are considered to be better suited to agriculture in the tropical monsoon environment (Singh et al. 2009). The changes in the characteristics of wet spells with a greater spread and lesser intensity are favorable in the study region as the number of wet spell days are increasing. While these results are true as an indication of possible changes that are happening with intra-seasonal distribution of monsoon rainfall, they do not hold any statistical significance. A more comprehensive study involving statistical analysis would be required for obtaining a better picture of the changes in the characteristics of the wet spells.

Global trends in climate change literature indicate an increase in extreme weather events in a changing climate (Easterling 2000). This statement does find resonance in some studies on the Indian monsoon, which indicate an increase of 5-10% in overall monsoon rainfall with higher inter-annual variability (Turner et al. 2012). In another statistical study on wet and dry spells over central India from 1951-2003, analysis reveals that frequency of the short dry spells (3 days) and moderate wet spells (4-7 days) have increased, with the area that is prone to dry spell like conditions found to be increasing after 1977 (Singh 2013). While another study with analysis of rainfall data from 1951-2011 indicates that statistically significant decreases in peak-season precipitation over the core-monsoon region have co-occurred with statistically significant increases in daily-scale precipitation variability (Singh et al. 2014).

The increased variability in the trends observed and predicted in relation to the intra-seasonal rainfall reinforce the intrinsically unpredictable nature of the intra-seasonal variations in the monsoon, whose underlying physical mechanisms are still not well understood (Krishnamurthy et al. 2000).

b. Changes in cropping systems from 1971-1990 to 1991-2004:

The changes in cropping systems indicate a significant decrease in the diversity of crops sown, which have decreased from 23 to 10 in the Kharif (monsoon) season with a shift from traditional inter-cropping system to a monocropping system. These changes in diversification patterns of rainfed agriculture, along with conversion of the cropping systems, are triggered by rapid technological changes in agricultural production, improved rural infrastructure, changing socio-economic variables like land and family sizes, and changes in resource endowments like water and labour (Pingali et al.1995).

The maturing of green revolution technologies initiated in the 1970's, by extending to more crops other than rice and wheat which was its initial focus, increased the regional spread of the technology to rainfed tracts of India, of which the study region is a part. This access to technologies was further aided by the government policy to bring better access to institutional credit in these regions for improving irrigation facilities. This coupled with the agricultural development programs like watershed development projects which emphasized on rain water harvesting for increased access to irrigation, brought about a major shift in cropping systems from coarse cereals, which were better adapted to the rainfed regions with arid agro-climate, to crops like paddy, facilitated by high-yield variety seeds and access to fertilizers and pesticides.

A paucity in data pertaining to the increased access to irrigation since the late 80's hampers the study to assess the exact increases in area under irrigation, which underwent major changes in extent and intensity of water access with bore wells replacing the dug wells in the region. The practice of accessing irrigation through bore wells has been a continuous process from then, with a lot of investments going into drilling of bore wells.

Favorable government pricing policies, assured procurement, and high-yielding technologies have also encouraged farmers to take up paddy production in irrigated areas. This has typically been the scene since the early 90's with paddy being the preferred crop, dominating areas with access to irrigation in the Doulthabad Mandal. This scenario of crops grown under irrigation has only changed recently, with an increased demand for ground nut crop which has resulted in ground nut crop occupying a significant area of the non-irrigated land through a late-Kharif sowing with access to micro-irrigation. This coupled with the good market prices was cited by farmers to be the primary reason for the increases in the area under groundnut crop.

Access to credit both from public sector banks initially, and more recently in the first decade of the 21st century in the form of micro-finance, has also had an influence on the cropping diversification of the farmers in the region. Access to credit has increased the risk bearing ability of the farmers with most of the credit being utilized for getting access to irrigation, or for purchases of agricultural inputs. This increased risk bearing ability, along with access to technology, could be explained as one of the reasons for the spread of hybrids of cotton and maize in the black soil regions of the Doulthabad Mandal.

These factors relating to improved credit availability, which is making both the exploration of irrigation opportunities and improved technology in seeds and fertilizers more accessible to the farmers in the study villages, have been cited by the farmers as the chief reasons for the shift in cropping to paddy in regions where irrigation is available. The other reason cited by these farmers for the shift to paddy is due to the government policy of announcing minimum support price (MSP) for procurement of the paddy crop, which both gives them reasonable income along with providing fodder for their large ruminants (mostly bulls and buffaloes).

Changes in crop diversification have also been influenced by improvement in infrastructure in the form of roads and markets (Joshi et al. 2007). Expansion of rural roads reflected in the strengthening of local market-related infrastructure, has encouraged farmers to break away from their subsistence type of production. The availability of markets, which have steadily offered higher prices for pulses like red gram and green gram as compared to the coarse cereals like foxtail millet, finger millet etc. that are more suited to the region, has been mentioned by the farmers as the reason for the loss of coarse cereals in their cropping diversity. The coarse cereals accounted for 6 of the 23 crops in the traditional cropping system.

While the above discussion focuses mainly around external drivers that have contributed to the reduction of diversity in traditional cropping systems, there have also been internal triggers relating to the socio-economic conditions of the farmers that have contributed to this change. The earlier intercropping systems involving a diversity of crops sown was made possible with the contributions from family labour. The socio-economic changes witnessed in the Doulthabad Mandal post the 1990's have resulted in land holdings and shrinking of family sizes. Less availability of family labour coupled with escalating labour costs, has meant that the labour costs involved in practicing a higher diversity through intercropping have been higher when compared with monocropping. This was attributed as one of the chief reasons by the farmers for the dwindling of the practice of intercropping.

c. Changes in risk with changing cropping systems:

Overall productivity of rainfed agriculture is central to farmers' attitudes that explain the shift in cropping systems. In the focus group discussions, farmers always preferred the current cropping system over the traditional inter-cropping system as the productivity of their lands has increased a great deal with access to external drivers like improved technology, irrigation, credit, and infrastructure along with government policy.

Underlying these changes in the cropping systems and their rationale by farmers is an undermining of risk management in rainfed areas. Neither does the farmer perceive traditional inter-cropping systems to have any role in managing weather related risk, nor is the increased investment brought about by current monocropping systems seen as a source of risk in the event of weather related contingencies. The farmer, in his experience of agriculture states that even though traditional cropping systems were characterized by better adaptation to droughts and yield compensation, the productivity per acre was very low in comparison with the present yields.

The traditional inter-cropping systems had 23 crops of which 12 crops require relatively less intensity rains for a lesser duration, thus making them more resistant to variability in the monsoon in the form of longer dry spells. These 12 crops with better ability to withstand drought also reduce the risks on farm incomes in the event of a drought. This ability of reduced risk is minimized in the current cropping systems where there is a very high income risk associated with production in the event of occurrence of a drought.

The fact that traditional cropping systems had a very high spread of crops dispersed across a long temporal window from late May to early November renders certain flexibility in decisions relating to cropping. For example, if a wet spell in early June is not followed by subsequent wet spells till late July, a loss to green gram crop can be compensated by sowing thymol seeds, cowpea, niger, finger millet, pearl millet, foxtail millet or sunflower (can be understood from Table 5).

This flexibility in selection of crops based on the onset of the first wet spell of the monsoon is restricted under the current cropping systems, which also have a sowing range from late May to early November with no cropping windows existing between mid-July to mid-October on lands that are purely rainfed. Adding to the risk is the fact that the seeds of the traditional crops and varieties are no longer available with the farming community in the current time period.

Research indicates that inter-cropping practices show a complementarity in efficient use of nutrients, moisture and light (Willey et al. 1987) and are particularly well-suited to semi-arid regions by imbibing production related risks through yield compensation. For example, in an inter-crop combination of Pearl Millet, Sorghum (Yellow Peri Carp) and Red Gram, a loss of Sorghum crop due to lack of adequate moisture requirement in mid-June can trigger greater tillering in Pearl Millet. This cannot be achieved when Pearl Millet as a solo crop is sown.

The paradigm of agricultural development post green revolution places a lot of importance on irrigation, with most of the government support being directed towards crops grown under irrigated conditions. Even in the Doulthabad Mandal, farmers perceive growing paddy in an acre of land to be more convenient, both in terms of operational ease and profitability as compared to any crop combination on non-irrigated lands. This idea of agricultural growth subjects the farmers to a lot of pressure in continuously exploring irrigation opportunities through drilling of new bore wells. The process of drilling borewells for irrigation is a money consuming process where the chances of accessing ground water are unpredictable. This paradigm of agricultural growth is further exacerbated by higher investments in usage of inputs, most of which are loans.

This reduction in the diversity of crops sown has mostly excluded food crops like millets, which were cultivated in the region. These food crops, which are not sold in market, are important for household food security and nutritional security. Also, when cash crops fail, the household has to buy food from outside because of non-reliance of food crops requirements in agricultural production, further adding to the risk of the households by increasing consumption credit.

CHAPTER 5: CONCLUSION

It should be noted that this study analyzes a very limited sample size with only 24 farmers being involved in the focus groups, and is restricted to 3 villages in the Doulthabad Mandal. While this study provides us with a representative picture of the traditional cropping systems along with the current cropping systems in place in the Mandal, an extension of these cropping systems beyond the boundaries of the Mandal or for the rainfed regions as a whole is fraught with a lack of understanding of the diversity in agro-climates, natural resource base, and also the social, economic and cultural characteristics of the people of the region, which culminate in the decision making process of the farmers on their cropping patterns. The results of this study in this regard, are useful in building a structural argument around the nature of agricultural growth pursued in India post green revolution, and in understanding the way it has marked the changes in the cropping systems from their traditional form to their current form in rainfed regions of India.

Most literature sources as mentioned in the discussion section, point towards an increasing variability of the intra-seasonal monsoon rainfall. Rainfall related production risk, which has been a reality in rainfed agriculture, will only be accentuated by the reduction in diversity of cropping systems. This reduction in diversity along with changes in cropping systems have been brought about by a paradigm of agricultural growth designed on the model of the green revolution by different participants involving the government, research community, the private sector, extension agencies and the farmers. The initial decade of introduction of the green revolution technologies was characterized by productivity and income gains, while the latter periods witnessed an increase in use of inputs with increasing evidence of input use inefficiency and a slowdown in public investment and input subsidies (Bhalla et al. 2010). The period also saw a deepening stress on water resources and rapid environmental degradation. These factors have continuously tended to increase the risks involved in practicing agriculture in rainfed regions. This picture calls for a rethink on the growth paradigm for agriculture with lesser risks involved and the concerns of sustainability not being compromised.

While it is important that strategies like decentralization be incorporated in planning and managing agricultural growth, these strategies should engage more on concepts like diversification in an effort of making agriculture less risky and sustainable. This study would recommend that new research needs to emerge on how the practice of crop diversification can be promoted such that the both aspects of income generation and also risk management can be promoted in rainfed agro-ecosystems. This approach then places a need for a participatory research between the farming and the research communities to evolve crop diversification as a practice that is suited to the agro-climates of the agricultural region, and provides a buffer to manage rainfall related risks in a scenario of increased rainfall variability along with maximizing productivity and returns from agriculture. The answers could only come from sustained engagement of the research and farming community in action research, and will only find a practical application when there is a political will to bring along policies that would encourage diversification in the same manner as was the case with green revolution technologies.

Reference List:

Alderman H & Paxson CH. 1992. “Do the Poor Insure? A Synthesis of the Literature on Risk and Consumption in Developing Countries," Papers 164, Princeton, Woodrow Wilson School - Development Studies.

APDAI 2005. Drought in Andhra Pradesh: Long term impacts and adaptation strategies: Volume 2. South Asia Environment and Social Development Department World Bank.

Bhalla GS and Singh G. 2010. Growth of Indian Agriculture: A District level Study. Final Report on Planning Commission Project. Government of India.

Blanford HF. 1886. Rainfall of India. Mem. India Meteorological Department 2:217–448.

Census of India. 2011. Government of India.

CRIDA 2011. Vision 2030, Central Research Institute for Dryland Agriculture, Santoshnagar, Hyderabad, India, pp:31.

Dixon J and Gulliver A.2001. Farming Systems and Poverty: Improving Farmers livelihood in a changing world. FAO and World Bank (Rome and Washington D.C.).

Dhawan B. 1988.Irrigation in India’s Agricultural Development. New Delhi: Sage Publications.

Directorate of Economics and Statistics, Andhra Pradesh (Records for the year 2009 and 2011).

Easterling DR, Evans JL, Groisman PY, Karl TR, Kunkel KE, Ambenje P. 2000. Observed Variability and Trends in Extreme Climate Events: A Brief Review. Bulletin American Meteorological Society, 81, 417–425.

FAO.1995. Sustainable dryland cropping in relation to soil productivity. FAO soils bulletin. Version 72.

Geilfus F. 2008. 80 tools for participatory development: appraisal, planning, follow-up and evaluation. Inter-American Institute for Cooperation on Agriculture (IICA), San José, Costa Rica.

Heitzman J and Worden RL (Eds). 1995. India: A Country Study. Washington: GPO for the Library of Congress.

Kanwar J. 1982. Problems and potentials of vertisols and alfisols-The two important soils of SAT-ICRISAT experience. Tropical Agriculture Research Series No 15. Tropical Agriculture Research Center, Japan.

Kerr JM. 1996. Sustainable Development of Rainfed Agriculture in India. EPTD Discussion paper 20.

http://www.ifpri.org/sites/default/files/publications/eptdp20.pdf

Krishnamurthy V and Shukla J. 2000. Intaseasonal and inter annual variability of rainfall in India. Journal of Climate, Volume13.

Kulkarni H, Vijay Shankar PS and Krishnan S. 2009. Synopsis of groundwater resources in India: Status, challenges and a new framework for responses. Report submitted to the Planning Commission, Government of India. ACWA Report ACWA/PC/Rep – 1.

Narendranath G. (2010). Dilemmas in Agriculture: A Personal Story. Vasudhaiva Kutumbakam Publication.

Pingali PL and Rosegrant MW. 1995. Agricultural Commercialisation and Diversification: Processes and Policies. Food Policy, 20(3): 171-86.

Rajeevan M, Bhate J, Kale J and Lal B. 2006. High resolution daily gridded rainfall data for the India region: Analysis of break and active monsoon spells. Current Science, 91, 296-306.

Rajeevan M and Bhate J. 2008. A High Resolution Daily Gridded Rainfall Data Set (1971-2005) for Mesoscale Meteorological Studies. Indian Meteorological Department, National Climate Centre, Research Report No: 9/2008

Ramachandran R. 2000. Dealing with drought. Frontline, Volume 17 - Issue 12, June 10 - 23, 2000.

Ramamurthy K. 1969. Monsoon of India: some aspects of the ‘break’ in the Indian southwest monsoon during July and August. Forecasting Manual 18.3(No. IV):1–57. India Meteorology Department, Poona, India

Rao KG, Goswami BN, Sikka DR, Gadgil S. 1978. Large-scale rainfall over India during the summer monsoon and its relation of the lower and upper tropospheric vorticity. Indian Journal of Meteorology Hydrology and Geophysics.29:219–31

Rao KN, George CJ, and Ramasastri KS. 1970. The climatic water balance in India. Memoirs of Meteorological Department. Indian Meteorological Department.

Rao AVRK, Wani SP, Singh P, Irshad Ahmed M and Srinivas K. (2006) Agro climatic Characterization of APRLP-ICRISAT Nucleus Watersheds in Nalgonda, Mahbubnagar and Kurnool Districts :Global Theme on Agro ecosystems. Research Report no 30. International Crops Research Institute for the Semi-Arid Tropics, Patancheru, Andhra Pradesh, India.

Report of the working group on risk management in agriculture for the 11th five year plan (2007-2012). Government of India, Planning Commission.

Shah A and Sah DC. 1993. Dryland farming under the changing source environment: A case study of Gujarat. Artha Vijnana 35 (3) (September).

Sharma BR, Rao KV, Vittal KPR, Ramakrishna YS and Amarasinghe U. 2010. Estimating the potential of rainfed agriculture in India: Prospects for water productivity improvements. Agricultural Water Management, Volume 97, Issue 1, January 2010, Pages 23-30.

Singh C. 2013. Journal of Atmospheric Research., Volume 128, p. 120-128.

Singh D, Tsiang M, Rajaratnam M and Diffenbaugh NS. 2014. Nature Climate Change 4, 456–461.

Singh RP and Jodha NS. 1986. Determinants of intercropping in Indian semiarid tropics: Causes and consequences. Mimeo, Economics Group, Resource Management Program. Patancheru: ICRISAT

Singh N and Ranade AA. 2009.Climatic and Hydroclimatic Features of Wet and Dry Spells and their Extremes across India. Indian Institute of Tropical Meterology. Research Report No: RR-122.

Singh S and Rathore MS (Eds.).2010. Rainfed Agriculture in India: Perspectives and Challenges. Rawat Publications.

Turner & Annamalai. 2012. Climate Change and the South Asian Monsoon. Nature Climate Change 2: 587-595.

Venkateswarlu J. Report on Integrated Watershed Development Program. Unpublished.

Vijay Shankar PS. (2011): Towards a paradigm shift in India's rainfed agriculture, Innovation and Development, 1:2, 321-322

Virmani SM, Sivakumar MVK and Reddy SJ. 1978. Climatological features of the SAT in relation to the Farming Systems Research Program. Proceedings of the International Workshop on Agroclimatological Research Needs of the Semi-Arid tropics (22-24 November, 1978, Hyderabad, India), 5-1 6.

Walker TS and Ryan JG. 1990. Village and Household Economics in India's Semi-arid Tropics. Baltimore: The Johns Hopkins University Press.

Willey RW. 1981. A scientific approach to intercropping research. In Proceedings of the International Workshop on Intercropping. 4-14, January 10-13,1979,ICRISAT Center. Patancheru: ICRISAT.

Annexure-1

Classification of villages in Doulthabad Mandal on the basis of soil type

Villages with dominant soil type as red soils	Villages with dominant soil type as black soils
Challapur	Yamki
Eerapally	Anthwar
Suraipallu	Bichal
Saleempur	Kudurmalla
Imdapur	Nandaram
Doulthabad	Neetur
Gokafaslawad	Maator
Timareddipalle	Chandrakal
Allapur	Kuppagiri
Sultanpur	
Tirmalapur	
Nagasar	
Polkampally	
Gundepalle	
Balampeta	
Challapur	

Annexure-2

Questionnaire for focus group Discussions

This questionnaire was run independently with different groups to capture both the cropping systems which existed in the time period from 1971-990 and 1991-2004.

1. Brief description of soils, monsoons, topography and history of the village

2. What are the chief constituents (sizes of lands, population of animals) of the farming systems and their relative importance (in terms of the income generation from each component)?

3. What are the expectations of the farmers from each of these components? (Household food requirements, sale of harvested crop, sale of livestock, etc)

4. Average range of land holding of the farmers in the focus group

	Acreage	Soil types
Rainfed		
Irrigated		

5. Chief crops grown on Rainfed land and irrigated land and the various cropping systems in place

6. Sources of irrigation and any patterns of rainfall in these regions.

7. Range of crop yields and labour requirements in a normal year and a drought year and the quality of the yield

8. Kharif(Monsoon) cropping pattern and cropping system (Mixed mono or other) and reasons for choosing them and implications in terms of adapting to dry spells.(karthe system on rainfed and irrigated soils of different types and the rationale behind selection of these crops)

1st Wet spell in →	Rohini	Mrugasira	Aarudra	Punarvasu	Pushyami	Aasles ha	Makha	Pubba	Uttara	Hastha
Crops Sown										

9. Inter-crop combinations of the crops and yields from each crop

10. Biophysical, social and economic attributes of cropping systems:

Nutrient cycling capacity, soil and water conservation capacity, stability towards pests and diseases

11. Dug wells and their regeneration capacity in a normal year and drought year and how variation in water level impacts yields and how do farmers adapt to changes in water levels.

12. Pest incidence in the crops and how was it controlled in the cropping systems of the time.

13. Nature of erosion and its control techniques.

14. Incomes from livestock?

15. Interface between agriculture and livestock. How did they complement each other?

16. How did the farmers perceive droughts in that time period and in what manner did its impacts manifest at different stages of plant growth?

17. How was the yield in a drought year as compared to a non-drought year? and were the farmers able to meet the requirements of the food for their family?

18. Did their cropping system in any way aid them in mitigating the yield losses that could have occurred due to drought?

19. Role of livestock in income diversification during times of drought.

20. Impacts of droughts on irrigated yields.

21. Other measures that contributed to improving resilience of farming systems.

Annexure 3

Wet Spell Periods

Year	FirstDay	LastDay	Total Wet Spell Rainfall
1971	05/06/71	12/06/71	40.2
1971	06/07/71	16/07/71	60.1
1971	20/08/71	09/09/71	134.5
1971	02/10/71	15/10/71	86
1972	26/06/72	08/07/72	133.7
1972	09/06/72	14-09-72	34.1
1972	05/10/72	12/10/72	40.7
1972	23-11-72	30-11-72	39
1973	01/06/73	10/06/73	50.7
1973	26/06/73	14/07/73	141.6
1973	13/08/73	01/09/73	103.4
1973	18/09/73	04/10/73	137.9
1973	22/10/73	01/11/73	74.9
1974	29/07/74	22/08/74	176
1974	07/09/74	18/1/1974	250.4
1974	20/10/74	06/11/74	169.8
1975	26/06/75	04/11/75	76.4
1975	30/07/75	26/08/75	156.8
1975	27/08/75	03/10/75	335.4
1975	04/10/75	16/11/75	270.9
1976	21/06/76	02/07/76	69.9
1976	03/07/76	01/08/76	231.9
1976	02/08/76	19/08/76	130.4
1976	20/08/76	24/09/76	179.8
1976	18/11/76	29/11/76	69.7
1977	05/07/77	14/07/77	50.7
1977	23/07/77	31/07/77	46
1977	10/08/77	01/09/77	199.4
1977	27/09/77	19/10/77	185.9
1978	22/05/78	01/06/78	59.3
1978	10/06/78	02/07/78	126
1978	03/07/78	07/08/78	335
1978	08/08/78	05/09/78	200.5
1978	10/09/78	15/10/78	307.6
1979	13/05/79	25/05/79	293.7
1979	21-06-79	27-06-79	51
1979	23/07/79	12/08/79	102.7
1979	09/09/79	15/10/79	251.5
1980	06/12/80	19-06-80	28.5

1980	07/01/80	07/11/80	42.6
1980	21/07/80	08/08/80	97.9
1980	13/08/80	22/08/80	43.8
1980	30/08/80	06/09/80	41.8
1981	23/06/81	03/07/81	57.3
1981	06/07/81	14/07/81	46.7
1981	27/07/81	19/08/81	144.1
1981	27/08/81	13/09/81	91.7
1981	02/09/81	14/09/81	72.9
1981	18/09/81	19/10/81	209.3
1982	14/06/82	24/06/82	61.8
1982	07-07-82	25-07-82	96.3
1982	29/7/82	08-05-82	35.4
1982	08-08-82	25-08-82	89.4
1982	08-09-82	18-09-82	58.4
1982	21-09-82	10-08-82	103.8
1982	20-10-82	11-12-82	149.7
1983	05-06-83	15-06-83	55.8
1983	24/06/83	07-01-83	37.1
1983	17-07-83	30/07/1983	84.5
1983	31-07-83	09-02-83	228.7
1983	07-09-83	13-10-83	240.6
1983	27-10-83	11-06-83	56.7
1984	11-06-84	20-06-84	47.7
1984	12-07-84	14-08-84	253.4
1984	11-09-84	29-09-84	106.3
1984	09-10-84	23-10-84	76.9
1985	27-07-85	15-08-85	137.4
1985	03-09-85	14-09-85	61.4
1985	01-10-85	14-10-85	68.3
1986	06-06-86	13-06-86	28
1986	13-07-86	25-07-86	64.8
1986	30-07-86	08-06-86	42.1
1986	07-08-86	24-08-86	90.2
1986	15-09-86	10-08-86	119.5
1987	15-06-87	22-06-87	32.4
1987	01-07-87	18-07-87	89.4
1987	04-08-87	09-12-87	218.1
1987	02-10-87	16-10-87	75.4
1987	16-10-87	28-10-87	64.5
1987	04-11-87	30-11-87	239.7
1988	31-05-88	15-06-88	81.1
1988	19-06-88	26-06-88	33.6
1988	15-07-88	09-03-88	255.5
1988	15-08-88	10-02-88	245.3

1988	05-09-88	18/10/1988	338
1989	30-05-89	14-06-89	86.5
1989	06-07-89	08-08-89	217.7
1989	24-08-89	31-08-89	28.7
1989	08-09-89	30-09-89	103.8
1990	11-05-90	20-05-90	51.2
1990	05-06-90	20-06-90	83.7
1990	08-07-90	08-03-90	150.8
1990	07-08-90	15/09/1990	309
1990	22-09-90	10-12-90	92.9
1990	25-10-90	11-10-90	119.4
1991	06-06-91	29/6/1991	166.7
1991	06-07-91	28/7/1991	146.4
1991	08-02-91	08-09-91	39.5
1991	10-09-91	10-05-91	311.5
1991	30-10-91	11-06-91	41
1991	07-11-92	18-07-92	30.2
1992	10-08-92	25-08-92	80.7
1992	09-10-92	20-10-92	60.7
1992	1-09-92-	09-10-92	49.9
1992	17-11-92	25-11-92	44.4
1993	07-01-93	07-08-93	29.7
1993	07-11-93	18-7-93	38.8
1993	23-07-93	08-10-93	95.6
1993	26-08-93	09-06-93	60.4
1994	20-9-93	27-9-93	30.8
1995	30-9-93	10-07-93	28.8
1993	08-10-93	29/10/1993	174.4
1994	21-5-94	28-5-94	28.4
1994	30-06-94	18-07-94	102.7
1994	24-07-94	08-01-94	45.5
1994	08-11-94	18-8-94	32
1994	22-08-94	09-02-94	61.8
1994	04-10-94	18-10-94	157.4
1994	19-10-94	31-10-94	66.4
1995	22-06-95	15-07-95	135.8
1995	16-07-95	08-08-95	156.9
1995	25-08-95	09-10-95	90.5
1995	11-09-95	10-08-95	185
1995	09-10-95	11-04-95	173.3
1996	27-05-96	06-10-96	73.1
1996	09-06-96	26-06-96	153.1
1996	17-07-96	26-07-96	48.4
1996	11-08-96	23-08-96	65.5
1996	25-08-96	26-09-96	226

1996	28-09-96	10-10-96	70.9
1996	19-10-96	11-01-96	71.6
1997	02-07-97	14-07-97	65.1
1997	27-08-97	15-09-97	166.5
1997	16-09-97	10-11-97	132.7
1998	20-06-98	07-02-98	71.4
1998	07-05-98	21-7-98	70.2
1999	28-07-98	08-04-98	36.7
1998	11-08-98	21-08-98	55
1998	05-09-98	13-10-98	193.3
1998	04-10-98	25-10-98	109
1999	10-06-99	21-06-99	57.9
1999	13-07-99	08-03-99	109.1
1999	25-08-99	09-03-99	48.3
1999	07-09-99	16-09-99	51
1999	29-09-99	10-06-99	32.4
2000	06-05-00	16-05-00	53.5
2000	02-06-00	26-06-00	143
2000	27-06-00	29/7/2000	194.1
2000	06-08-00	18-08-00	77.9
2000	19-08-00	14-09-00	241
2000	17-09-00	14-10-00	93.4
2000	10-08-00	15-10-00	33.3
2001	05-06-01	16-06-01	58.5
2001	02-08-01	28-08-01	153.3
2001	09-09-01	23-09-01	89.3
2001	24-09-01	30-10-01	356.2
2002	15-05-02	22-05-02	40.5
2002	30-05-02	06-10-02	61
2002	15-06-02	23-06-02	44.8
2002	14-07-02	24-07-02	60.4
2002	25-07-02	08-04-02	74.2
2002	05-08-02	29-08-02	165.2
2002	30-08-02	09-11-02	62.6
2002	12-10-02	27-10-02	193.4
2003	23-06-03	7.6.03	87.9
2003	07-07-03	30-07-03	161.7
2003	02-08-03	09-06-03	251.6
2003	24-09-03	10-09-03	77.7
2003	19-10-03	11-06-03	92.9
2004	14-5-04	21-05-04	29.4
2004	06-05-04	06-12-04	32.9
2004	09-07-04	18-07-04	52.4
2004	24-07-04	08-10-04	90.6
2004	04-09-04	17-09-04	69.4

2004	02-10-04	23-10-04	131.7

Annexure-4

Telugu Karthe and the Gregorian Calendar

Telugu Month	Starting Date	Ending Date
Rohini	25th May	7th June
Mirugu	8th June	21nd June
Arudra	22nd June	5th July
Pushyami	6th July	19th July
Punarvasu	20th July	2nd Aug
Aslesha	3rd Aug	16th Aug
Makha	17th Aug	30th Aug
Pubba	31st Aug	12th Sep
Uttara	13th Sep	26th Sep
Hasta	27th Sep	10th Oct
Chitta	11th Oct	23rd Oct
Swati	24th Oct	5th Nov
Vishaka	6th Nov	18th Nov
Anuradha	19th Nov	1st December